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00617 | Research Article

Environmental and Agricultural Impacts of Deforestation in Uzo-Uwani Local Government Area of Enugu State, Nigeria

Ogbobe Gratitude Eziamaka[1], Moses Obenade*[2], Echem Ogba Samuel[3], Iroegbu Ngozi Franca[4], Onah Gladys Owere[5], Onyeka Stanley Chukwuedo[6], Omeri Kelvin Nwachi[7], Jacob Parkins Agwu[8], Patience Afor Ibeneme[9], Sylvester Uchechukwu Ibeneme[10]

[1]Department of Disaster Risk Management, Center for Excellence in Environmental Management and Green Energy, University of Nigeria, Enugu Campus, Enugu, Nigeria. Email: ogbobeeziamaka@gmail.com | ORCID: https://orcid.org/0009-0007-2170-0021
[2]Department of Geography, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State, Nigeria. Email: moses.obenade72@gmail.com | ORCID: https://orcid.org/0009-0005-5234-7190
[3]Department of Fine and Applied Arts, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State, Nigeria. Email: samchemcolours@gmail.com | ORCID: 0000-0001-9379-6420
[4]Department of Business Administration, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State, Nigeria. Email: iroegbufranca023@gmail.com | ORCID: 0009-0004-0774-4392
[5]Department of Business Administration, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State, Nigeria. Email: owere.gladys@funai.edu.ng | ORCID: 0000-0003-4878-4556
[6]Department of Accountancy, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State, Nigeria. Email: chukwuedoo@gmail.com | ORCID: https://orcid.org/0009-0008-9575-7626
[7]Department of Business Administration, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State, Nigeria. Email: omerikelvin@gmail.com | ORCID: 0009-0006-8354-2738
[8]Department of Geography, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State Nigeria. Email: agwuj70@gmail.com | ORCID: https://orcid.org/0009-0004-9075-9762
[9]Department of Geography, Alex Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State Nigeria. Email: patienceibeneme@gmail.com | ORCID: 0000-0002-8169-5072
[10]Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL), Wuye, Abuja, Nigeria. Email: uchesylvester@yahoo.com | ORCID: https://orcid.org/0000-0002-0052-5742
Corresponding author

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Abstract

Deforestation is a major threat to Nigeria's biodiversity loss and contributor to climate change. This research examines environmental and agricultural impacts of deforestation in Uzo-Uwani Local Government Area of Enugu State, Southeastern Nigeria with the aim of assessing the magnitude of change that has occurred among key environmental components or variables such as water bodies, vegetation, cultivated area, plantation area, bareland, and built-up area in Uzo-Uwani over a twenty years period (2000-2024) using geospatial techniques. The results show that water bodies increased by 1.02 km^2 representing a 485.71% change; built-up areas increased by 2.92km^2 representing 249.57%, change; vegetation decreased by (-288.77 km^2) representing (-49.58%) change; cultivated area increased by 229.33 km^2, representing 82.12% change; plantation increased by 55.5 km^2 representing 1761.90% change while bareland remains unchanged. The test of change in land use variables reveals that there is significant difference or change in land use between 2000 and 2024 which is evident by the p-value of the test statistic of 0.50 being greater than 0.05, hence at 5% level of significance. It further reveals current land use practices that impact negatively on the environment and also provide evidence-based insights for policy makers in the state. We therefore recommend promoting agroforestry in cultivated expansion zones, or community-based monitoring in plantation areas as well as taking other proactive and remedial measures to conserve and preserve the environment.

Keywords
Uzo-Uwani; Environment; Agriculture; Ecosystem; Deforestation

Introduction

Deforestation is the term used to describe the removal of forests by humans for the purpose of producing timber or to make way for other uses, like urbanisation or agriculture. Nigeria's rapidly expanding population and rising demand for fuelwood, timber, and agricultural land have exacerbated the country's deforestation problem. Nigeria has the highest rate of deforestation in the world, with an estimated 3.7% of its forest lost annually, according to the United Nations as quoted by the DGB Group (2023).

Deforestation has far-reaching and pervasive environmental effects. The natural equilibrium of ecosystems is upset by deforestation, which results in soil erosion, biodiversity loss, and local climate change. Large volumes of carbon dioxide are also released into the atmosphere as a result of it. By decreasing access to clean water and raising the risk of flooding and landslides, deforestation also has a detrimental impact on the local population (DGB Group, 2023). Deforestation contributes to soil erosion, biodiversity loss, wildlife decline, land degradation, and desertification, among other negative effects on the environment (GFW, 2015). Deforestation also severely affects agriculture, increasing the risk of conflict and reducing living standards. Primary forests show limited signs of direct human activity (GFW, 2025). The main cause of greenhouse gas emissions is deforestation, which increases the concentration of carbon dioxide (Cramer *et al*., 2004).

Nigeria's once-fertile land is at risk of desertification as a result of widespread deforestation. Nigeria's temperature increased by 1.1°C between 1901 and 2005, more than the global average of 0.74°C. The 1970s saw notable changes in rainfall, which dropped by 81 mm during that time (Akpodiogaga and Odjugo, 2010; Omofonmwan and Osa-Edoh, 2008). The need for fuelwood is the reason for the startlingly fast rate of deforestation. Approximately 90% of Nigerians cook with kerosene but 60% turn to fuel wood because it is either unavailable or too expensive. While poverty continues to be a major cause of deforestation, rural areas see higher usage, which affects livelihoods (Akinbami, Salami and Siyanbola, 2003; *Balarabe*, 2011; Mongabay, 2021).

According to Global Forest Watch (GFW, 2024), between 2001 and 2022, 12% of Nigeria's tree cover was lost, with deforestation occurring at a rate of 163 Kha annually. In addition to creating obstacles to afforestation efforts, human activities such as agricultural expansion, logging, urbanisation, and infrastructure development also contribute to deforestation. Concerns have been raised about Nigeria's deforestation because of its connection to poverty and its effects on the environment (Zhang, 2021). Climate change, logging, biotic agents, and human and organisational deforestation are some of the factors that contribute to deforestation in Nigeria. Urbanisation, logging, both legal and illicit, and the growth of agriculture are the main causes (Fasona *et al*., 2018). According to the Convention on Biological Diversity and Economic Confidentiality (2019), Nigeria is renowned for its ecological biodiversity and is regarded as one of the world's richest biodiversity hotspots, which greatly contributes to the nation's economic prosperity.

Maintaining forest resources, biodiversity, health, and productive, protective, and socioeconomic functions are among the standards for sustainable forest management set forth by the Food and Agriculture Organisation of UN (FAO). These standards are currently unmet, which could have negative consequences if left unchecked (FAO, 2018; Osemeobo, 1988). Evaluating the non-productive roles of forests is difficult. This has resulted in notable disparities in research findings on this subject. Some studies emphasized that the overall value surpasses the value of the effects of the productive functions, depending on the approach, primarily scale and area. The production of timber is the main purpose of commercial forests, however, and this should be done as sustainably as possible (Kriström, Boman and Kengen, 2001); Sikora and Wartecka-Ważyńska, 2017; Snarski, 2023). The definition of sustainable forest management, according to Źróbek-Sokolnik, Dynowski and Jarczyk (2024), is "an activity aimed at shaping the structure of forests and their use in a manner and at a rate ensuring the permanent preservation of their biological richness, high productivity and regeneration potential, vitality and capacity to fulfill, now and in the future, all important protective, economic, and social functions at local, national, and global levels, without detriment to other ecosystems".

According to Global Forest Watch (GFW, 2025), from 2002 to 2024, Enugu lost less than 1 hectare of humid primary forest, making up less than 0.1 % of its total tree cover loss in the same time period, thus total area of humid primary forest in Enugu decreased by 0.46% in this period. Also, from 2001 to 2024, Enugu lost 2.8 kha of tree cover, equivalent to 4.0% of the 2000 tree cover area, and generated 1.8 Mt of CO_2 emissions. This does not account for gains in tree cover over the same period, and in 2020, Enugu had 320 kha of natural forest, extending over 42% of its land area. In 2024, it lost 1.9 kha of natural forest, equivalent to 1.1 Mt of CO_2 emissions.

The Global Forest Watch also noted that in Enugu, the top four regions were responsible for 51% of all tree cover loss between 2001 and 2024. Udi had the most tree cover loss at 450 ha compared to an average of 160 ha. These four regions are Udi (450 ha), Enugu East (350 ha), Oji River (320 ha), Awgu (280 ha), Nkanu East (250 ha), and as of 2010, the top five regions represent 54% of all tree cover in Enugu. Udi had the most tree cover at 19 kha compared to an average of 6.8 kha. The five top regions are Udi (19 kha), Agwu (12 kha), Oji River (11 kha), Isi-Uzo (11 kha), and Nkanu East (9.9 kha).

The report equally stated that from 2001 to 2024, Enugu lost 4.0 ha of tree cover from fires and 2.8 kha from all other drivers of loss. The year with the most tree cover loss due to fires during this period was 2012 with less than 1 ha lost to fires representing 0.62% of all tree cover loss for that year while from 2001 to 2024, 100% of tree cover loss occurred in areas where the dominant drivers of loss resulted in deforestation. Global Forest Watch further reported that the major drivers of deforestation in Enugu were identified as hard commodities (25 ha), permanent agriculture (1.9 kha), settlements and infrastructure (730 ha) while drivers of temporary disturbances were logging representing less than 1 hectare. Other natural disturbances (3.0 ha) and shifting cultivation (6.0 ha).

Nzeh, Eboh and Nweze (2015) in their study concluded that deforestation and degradation of forest across the Nigeria and Enugu State in particular is an ongoing problem in most communities, mostly the government-ignored villages. The problem is seriously affecting human development in the rural area of Enugu State due to the loss of income and employment generation from this sector of the economy. They opine that proper identification of preventive and control measures which include among others adequate advocacy in this area of the negative effects of deforestation activities; afforestation projects across the state would be very useful. According to them, the key ways forward in this regard are the proper education of local people on the importance of non-wood forest products (NWFPs) and Non-Timber Forest Products (NTFPs) in their livelihood, and stress the constant need for stakeholders in the sector to ensure adequate budgetary provision in forestry management.

In the same vein, Odoh, Nwokeabia and Callista (2024) in their study also concluded that the analysis of LULC changes and slope dynamics between 2017 and 2023 in Enugu North, Enugu South, Nkanu East, and Nkanu West LGAs reveals significant trends with profound environmental and socio-economic implications. The most notable change is the substantial reduction in tree cover from 565.99 km² to 432.48 km², indicating extensive deforestation driven by urban expansion and agricultural land conversion. This reduction in forested areas threatens biodiversity, disrupts carbon sequestration processes, and alters local climate and hydrological cycles, underscoring the urgent need for effective forest conservation strategies.

From the foregoing, there is a knowledge gap in previous studies on the causes and implications of deforestation in Enugu State as none provides insights into the prevailing situations in Uzo-Uwani Local Government Area for which this study seeks to assess the magnitude of change that has occurred in terms of deforestation and its environmental and agricultural impacts using geospatial techniques.

Methodology

Study Area

One of the seventeenths (17) Local Government Areas in Nigeria's Enugu State is Uzo-Uwani. According to Ali and Asogwa (2017), Uzo-Uwani is situated between latitudes 6º 55’ N and 7º 15’ N and longitudes 6º 30’ E and 7º 00’ E. It shares boundaries with Benue State to the north and Kogi State to the west. These are the two neighbouring states that share borders with Uzo-Uwani. As illustrated in Figure 1, Uzo-Uwani LGA is bounded to the east by Nsukka LGA, to the south by Igbo-Etiti LGA, and to the southeast by Udenu LGA within Enugu State. According to the 2006 census, it has a population of 124,480 and an area of 866 km^2. Uzo-Uwani L.G.A. experiences tropical wet-and-dry (savanna) climates. The north-east plateau receives an average of 1,650 mm of rainfall annually, while the western lowlands receive 147 mm. According to Ali and Asogwa (2017), Uzo-Uwani L.G.A. is situated in the western lowland region of the Nsukka plateau, which slopes gently and gradually down to the Anambra plain on the western side. Yam, cassava, and maize are the main crops grown in the region, which has a predominantly agrarian economy. Natural resources like coal, limestone, and clay are also abundant in Uzo-Uwani and could help with industrial growth.

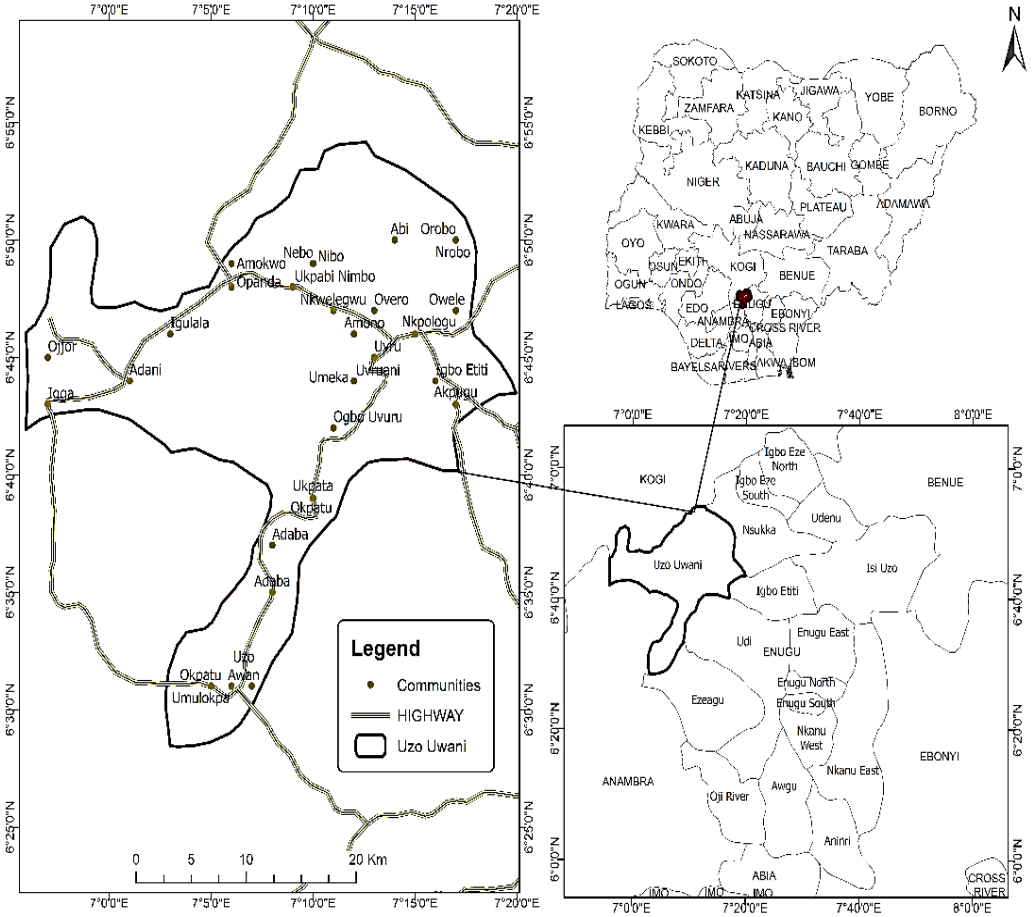

Figure 1: Location Map of the Study Area Prepared by the Authors

Description of Data

This study relied primarily on open-source secondary datasets, particularly satellite imagery, to generate the key input parameters used in the analysis Normalized Difference Vegetation Index (NDVI) and Land Use/Land Cover (LULC) maps. Series of archived satellite imagery tiles from (Sentinel-2) were utilized in realizing the aims and objectives of this research study. Parameters - NDVI and LULC were generated from Sentinel-2 satellite data. Launched in the first quarter of 2014, the Sentinel-2 satellites have 13 spectral bands in the visible, near-infrared, and shortwave infrared part of the spectrum that can be applied in the fields of Land use Land cover mapping, water resources and disaster management, and agriculture monitoring to detect ground deformation and providing support for disaster management.

The maps procured for this study include: topographic and administrative maps covering the study area. These maps were used as ancillary data to aid field work, image classification and the compilation of maps produced in the research work. The Maps were scanned, geo-referenced, and sub-map to area of interest after which they were digitized in order to extract the needed thematic layer into the work geo-database.

Table 1: Data and Data Sources

S/N	*Parameters*	*Data*	*Sources*	*Period*
1.	LULC	Sentine-2	Google Earth Engine https://explorer.earthengine.google.com	2024
2.	NDVI	Sentinel-2	Google Earth Engine https://explorer.earthengine.google.com	2024
3.	Administrative map of Nigeria	Shape	Office of the Surveyor General https://osgof.gov.ng/products-services/	

Table 2: Software, Tools, and Uses

S/N	*Software*	*Applications*
1.	ArcGIS version 10.8	GIS analysis
2.	Google Earth Engine app	Rainfall, LULC, and NDVI

Field Work

Ground truthing was also carried out to determine the nature of land use / land cover change and coordinates of site with the use of GPS. Historical land cover type and uses was also obtained via oral interviews on the field. In addition, important observation was made and recorded while verification was made on the unclassified False Color Composite (FCC) image carried along, in order to resolve conflicting pixel representations. The information acquired aided the interpretation and classification of the various image and their general accuracy assessment.

Data Analysis and Interpretation

Five main methods of data analysis were adopted in the study.

(i) Cluster analysis
(ii) Maximum Likelihood Classification
(iii) Calculation of the Area in hectares of the resulting land cover types for each study year and subsequently comparing the results.
(iv) Overlay Operations
(v) Error matrix and a Kappa analysis

The first two methods above were used for image classification to produce land cover map of the study area. The data were imagery of 2000, 2013 and 2024. Calculation of the Area in square kilometer assisted in identifying the percentage change, trend, and rate of change between the periods of investigation.

Land Cover Classification System

In this research, the FAO land cover classification system (LCCS) was used. Following the data and information acquired from the field, the land cover type of the study was generated. They included:

1. Cultivated and Managed Terrestrial Area (Farm/Fallow land): This area refers to areas where the natural vegetative cover has been altered and replaced by other

type of vegetative cover by human activities. This class encompasses all vegetative crops that are planted with the intent of harvesting.

2. Natural/Semi Natural Vegetation: natural vegetative areas are defined as areas where the vegetative cover is in balance with biotic and abiotic forces of the biotope. Semi Natural vegetative areas are those not planted by human but are influenced by human actions.
3. Artificial Surface and Associated Areas: this class defined areas that have artificial land cover as a result of human activities, these activities include construction sites, extraction sites, as a result of mining and excavations and waste disposal waste areas.
4. Bare areas described areas that do not have any artificial influence; these areas are those with very small litter or no vegetative cover at all such as rocks, bare sand and desert.
5. Natural Water Bodies: these are areas that are naturally covered by water, such as streams, lakes, rivers, etc.
6. Built-up areas: these include areas occupied by settlements/towns, companies, and infrastructures.

Development of a Classification Scheme

Based on the prior knowledge of the study area for over 14 years and a brief reconnaissance survey with additional information from previous research in the study area, the classification scheme was developed after FAO Land Cover Classification System (LCCS). They include Built-up area (BA), Cultivated Area (CA), Water body (WB), Vegetation (VE), Bare Land (BL), and Plantation Area (PL) as shown in table 3.

Table 3: Classification Scheme

Code	*Land Cover Categories*
CA	Cultivated Area
VE	Vegetation Area
BU	Built-up Area
PL	Plantation Area
WB	Water bodies
BL	Bare Land

Supervised Classification

The supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data [Richards, 1993, p85]. Using this method, the analyst has available sufficient known pixels to generate representative parameters for each class of interest. This step is called training. Once trained, the classifier is then used to attach labels to all the image pixels according to the trained parameters. The most commonly used supervised classification is Maximum Likelihood Classification (MLC), which assumes that each spectral class can be described by a multivariate normal distribution. Five training sites were identified and further classified into the classes listed in the schema.

Change Detection

One of the most common applications of change detection is determining urban land use change and assessing urban sprawl. This would assist urban planners and decision makers to implement sound solution for environmental management. A number of approaches have emerged and applied in various studies to determine the spatial extent of land cover changes. It has also been noted that different methods of detection produce different change maps (Araya and Cabral, 2008). Below are methods applied in this study.

Image Differencing

Image differencing is based on the subtraction of images acquired in two different times. This is performed on a pixel by pixel or band by band level to create the difference image. In the process, the digital number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date (Singh, 1989; Tardie and Congalton, 2004). Since the analysis is pixel by pixel, raw (unprocessed) input images might not present a good result.

Vegetation Index Differencing

This method is applied to analyze the amount of change in vegetation versus non vegetation by computing Normalized Deference Vegetation Index (NDVI). NDVI is one of the most common vegetation indexing method and is calculated by:

$$NDVI = \frac{NIR - RED}{NIR + RED} - 1.0 \quad \text{eqn1}$$

Where NIR is the near infrared band response for a given pixel and RED is the red response

Post Classification Comparison

This is the most obvious, common and suitable method for land cover change detection. This method requires the comparison of independently classified images T1 and T2, the analyst can produce change map which show a complete matrix of changes (Singh, 1989).

Post-Classification Detection Technique

Post classification technique is one of the most used and simple approach to detecting changes comparison (Blaschke, 2004). A post-classification comparison, which is the most straightforward technique, has been applied in this study. The land cover maps for the years 2000, 2013 and 2024 were first simplified into six classes. The post-classification comparison was then applied by differentiating the corresponding classified maps to generate change maps. The change statistics was generated as a table and subsequently used to calculate the frequency and magnitude of change. The result of the change detection entirely depends on the accuracies of each individual classification. Image classification and post-classification techniques are, therefore,

iterative and require further refinement to produce more reliable and accurate change detection results (Fan, Weng and Wang, 2007).

Table 4: Error Matrix and Kappa Analysis

Year	*Kappa Coefficient*	*Overall Accuracy*
2000	1.0	100%
2013	1.0	100%
2024	0.83	90%
Average	0.94	96.6

Results and Discussion

Land Use Land Cover Change from 2000 to 2024

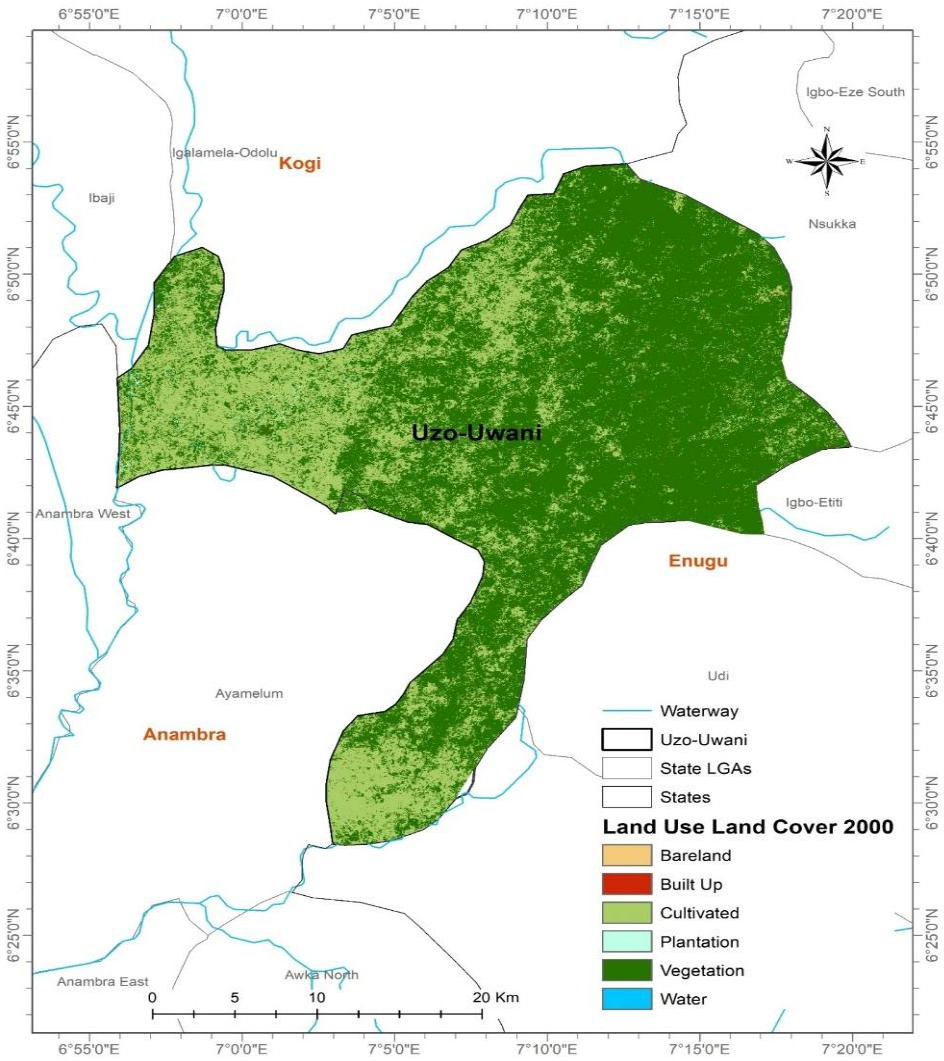

Figure 2: Land use land cover map of Uzo-Uwani, 2000

Figure 2 above shows the land use land cover satellite image of Uzo-Uwani in the year 2000 showing all the LULC classes: bareland, built-up, cultivated, plantation, vegetation, and water bodies.

Table 3: 2000 Land Use Land Cover Classes Distribution

S.N.	*2000 Class*	*Area (ha)*	*Area (km^2)*	*Area (%)*
1	Water	21.15	0.21	0.02%
2	Built Up	116.91	1.17	0.13%
3	Vegetation	58246.38	582.46	67.23%
4	Cultivated	27924.84	279.25	32.23%
5	Bare Land	9.45	0.09	0.01%
6	Plantation	315.45	3.15	0.36%
	Total	86634.18	866.34	100

Table 1 above shows the land use land cover classes distribution of the study area. In the year 2000, water bodies occupied an area of 0.21km^2 representing 0.02% of the area while built-up area, vegetation, cultivated, bare land, and plantation occupied 0.13%, 67.23%, 32.23%, 0.01% and 0.36% respectively. Vegetation occupied the largest area of 582.46km^2 followed by cultivated area with 279.25km^2.

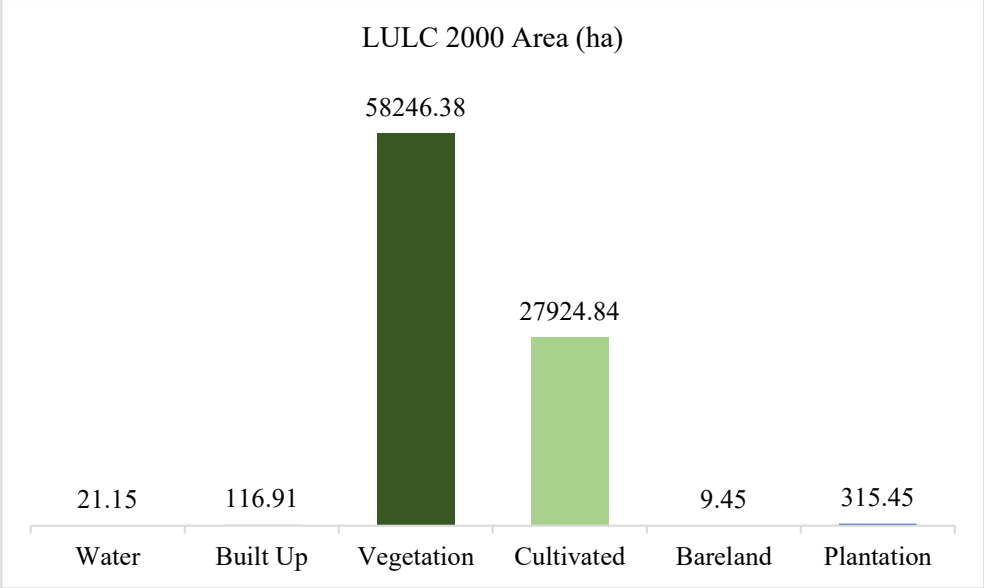

Figure 3: 2000 Land Use Land Cover Classes Distribution Chart

Figure 3 above shows the land use land cover classes distribution of the study area in the year 2000 indicating vegetation and cultivated area as the major classes of land use in the area.

Figure 4 shows the land use land cover satellite image of Uzo-Uwani in year 2013 indicating all the variables: bareland, built-up, cultivated, plantation, vegetation, and water bodies.

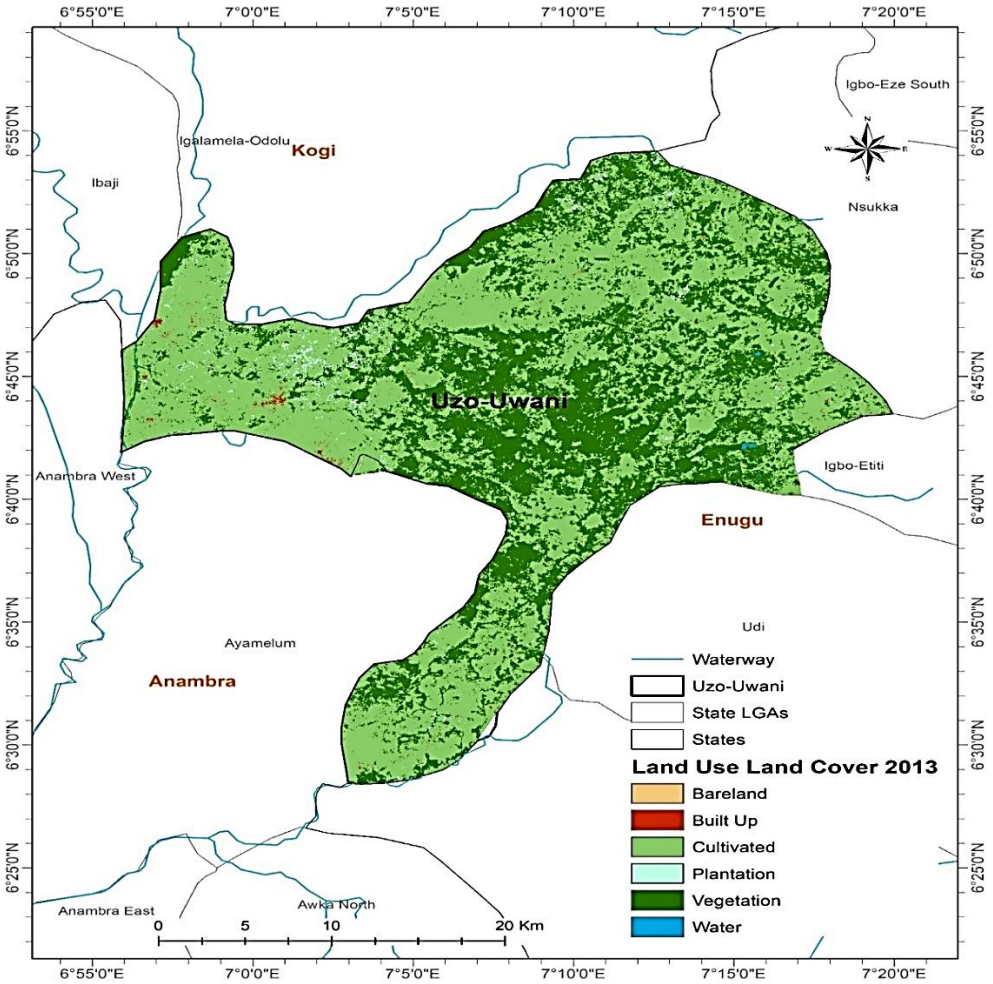

Figure 4: Land use land cover map of Uzo-Uwani, 2013

Table 4: 2013 Land Use Land Cover Classes Distribution

S/N	*2013 Class*	*Area (ha)*	*Area (km^2)*	*Area (%)*
1.	Water	85.14	0.85	0.10%
2.	Built Up	212.85	2.13	0.25%
3.	Vegetation	33148.35	331.48	38.26%
4.	Cultivated	51836.04	518.36	59.83%
5.	Bare Land	0.99	0.01	0.00%
6.	Plantation	1350.81	13.51	1.56%
	Total	86634.18	866.34	100

Table 4 above sows the land use land cover classes distribution of the study area in the year 2013 with water bodies occupying an area of 0.85 km^2 representing 0.10% of the area while built-up area, vegetation, cultivated, bareland, and plantation occupied 0.25%, 38.26%, 59.83%, 0.00% and 1.56% respectively. Cultivated land occupied the largest area of 518.36km^2 followed by vegetation with 331.48km^2.

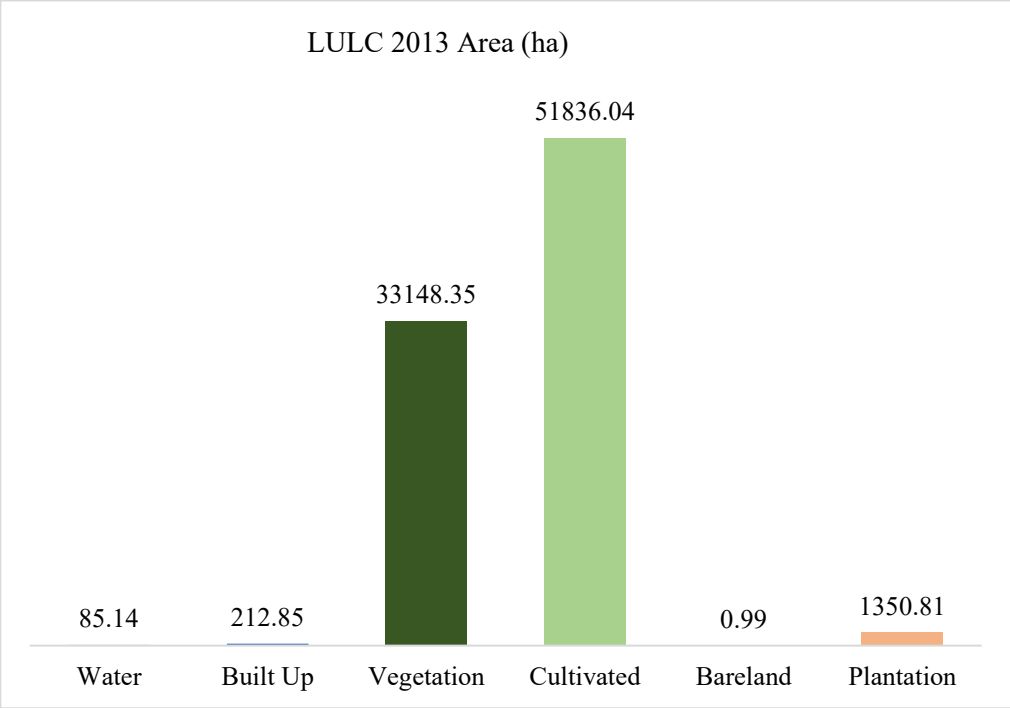

Figure 5: 2013 Land Use Land Cover Classes Distribution

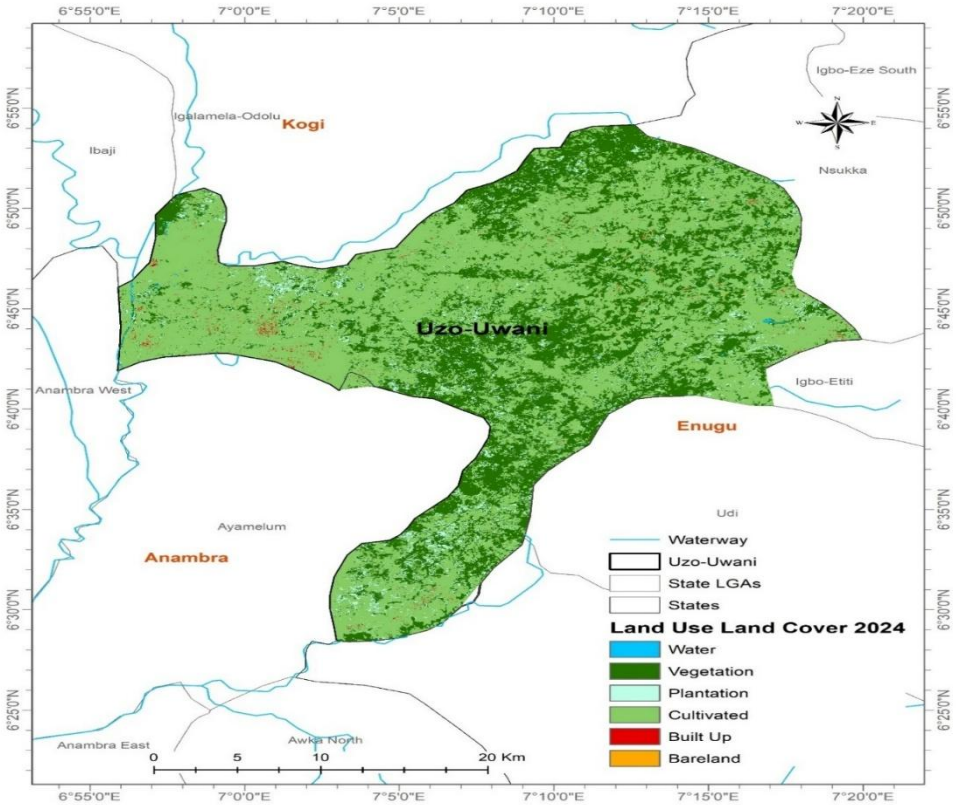

Figure 6: Land use land cover map of Uzo-Uwani, 2024

Figure 5 illustrates the distribution of land use and land cover classes in the study area for the year 2013. The dominant classes are cultivated land, followed by vegetation. This pattern indicates a notable shift in land use and land cover compared to the situation in the year 2000.

Figure 6 shows the land use land cover map of Uzo-Uwani in year 2024 indicating all the variables: bareland, built-up, cultivated, plantation, vegetation, and water bodies.

Table 5: 2024 Land Use Land Cover Classes Distribution

S.N.	*2024 Class*	*Area (ha)*	*Area (km^2)*	*Area (%)*
1	Water	123.12	1.23	0.14%
2	Built Up	409.41	4.09	0.47%
3	Vegetation	29369.34	293.69	33.90%
4	Cultivated	50858.19	508.58	58.70%
5	Bare land	8.91	0.09	0.01%
6	Plantation	5865.21	58.65	6.77%
	Total	86634.18	866.34	100

Table 5 presents the land use and land cover distribution for the study area in 2024. Water bodies cover 1.23 km², representing 0.14% of the total area. Built-up areas, vegetation, cultivated land, bare land, and plantations account for 0.47%, 33.90%, 58.70%, 0.01%, and 6.77%, respectively. Cultivated land is the dominant class, occupying 508.58 km², followed by vegetation, which covers 293.69 km².

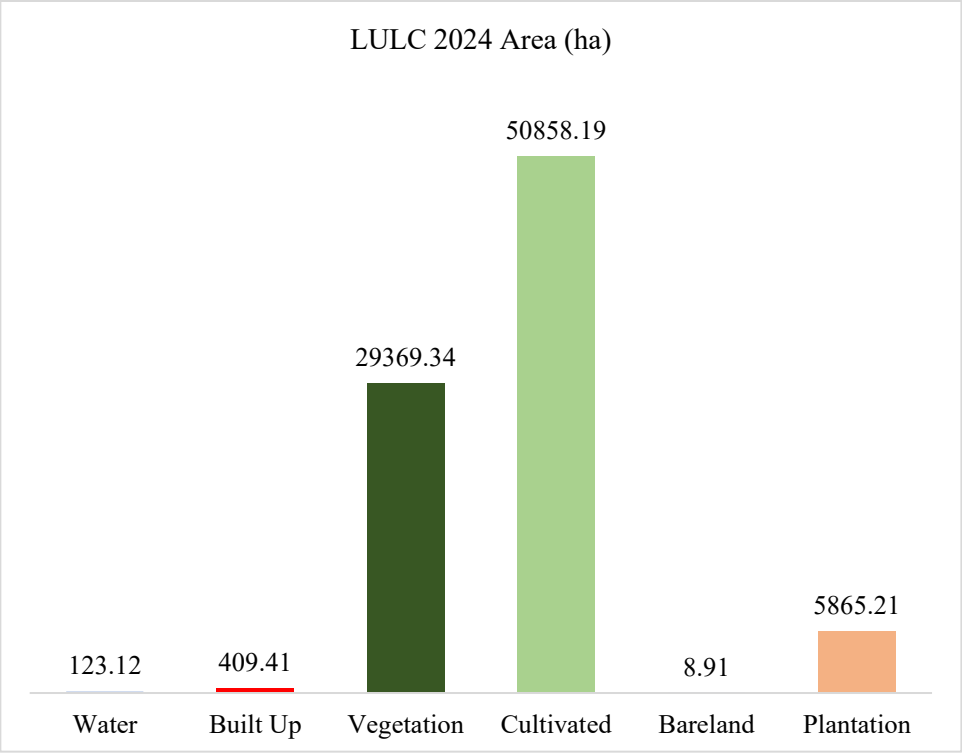

Figure 7: 2024 Land Use Land Cover Classes Distribution

Figure 7 above shows the land use land cover classes distribution of the study area in the year 2024. Cultivated area, followed by vegetation and plantation, are the dominant land-use classes in the area.

Table 6: Magnitude of Change and Percentage Change between 2000 and 2024

S.N.	*Class*	*2000 Area (km^2)*	*2024 Area (km^2)*	*Magnitude of Change (km^2)*	*Percentage Difference (%)*	*Percentage (%) Change*
1.	Water	0.21	1.23	1.02	0.12	485.71
2.	Built Up	1.17	4.09	2.92	0.34	249.57
3.	Vegetation	582.46	293.69	-288.77	-33.33	-49.58
4.	Cultivated	279.25	508.58	229.33	26.47	82.12
5.	Bare Land	0.09	0.09	0	0.00	0.00
6.	Plantation	3.15	58.65	55.5	6.41	1761.90
	Total	866.34	866.34			

The area's percentage change and magnitude of change between 2000 and 2024 are displayed in table 6 above. Over the study period, the area covered by vegetation decreased, while the area covered by bareland was constant. However, the area covered by water, built-up, and cultivated areas increased slightly, while the area occupied by plantations increased significantly. The area's rate of land conversion or deforestation is unsustainable, with clear implications for agriculture and the environment, as indicated by the vegetation's negative value. The land use dynamics indicate a significant shift from natural vegetation toward cultivated land, plantations, and built-up areas, while water bodies have expanded slightly and bare land remained negligible. These highlights intensified human activity and land development in the study area over the 24-year period.

Table 7: Test for the significance of the changes in Land use

Class	*2000*	*2024*	*Wilcoxon Signed Ranks Test (Z-value)*	*p-value*
Water	0.21	1.23	-0.674	0.500
Built Up	1.17	4.09		
Vegetation	582.46	293.69		
Cultivated	279.25	508.58		
Bare Land	0.09	0.09		
Plantation	3.15	58.65		
Total	866.34	866.34		

The Wilcoxon Signed-Ranks Test was applied to determine if the overall changes in LULC classes between 2000 and 2024 were statistically significant. The test produced a Z-value of -0.674 with a p-value of 0.500. Since the p-value (0.500) is greater than the standard significance level of 0.05, the result indicates that the observed changes in land use and land cover are not statistically significant at the 5% level. This suggests that while there are noticeable increases in cultivated land, plantations, water bodies, and built-up areas, and decreases in vegetation, these changes do not differ significantly from random variation in the dataset according to this test. The data show clear trends in land

transformation over the 24 years, but statistically, the Wilcoxon test indicates that these changes are not significant, possibly due to variability among the classes or sample size limitations.

Table 8: Magnitude of Change and Percentage Change between 2000 and 2013

S.N.	*Class*	*2000 Area (km^2)*	*2013 Area (km^2)*	*Magnitude of Change (km^2)*	*Percentage Difference (%)*	*Percentage (%) Change*
1.	Water	0.21	0.85	0.64	0.07	304.76
2.	Built Up	1.17	2.13	0.96	0.11	82.05
3.	Vegetation	582.46	331.48	-250.98	-28.97	-43.09
4.	Cultivated	279.25	518.36	239.11	27.60	85.63
5.	Bare Land	0.09	0.01	-0.08	-0.01	-88.89
6.	Plantation	3.15	13.51	10.36	1.20	328.89
	Total	866.34	866.34			

The percentage change and magnitude of change between 2000 and 2013 are displayed in table 8 above. This indicates that while the area occupied by vegetation and bareland decreased, the area occupied by water, built-up, cultivated land, and plantations increased.

Table 9: Test for the significance of the changes in Land use between 2000 and 2013

Class	*2000*	*2013*	*Wilcoxon Signed Ranks Test (Z-value)*	*p-value*
Water	0.21	0.85	-0.734	0.463
Built Up	1.17	2.13		
Vegetation	582.46	331.48		
Cultivated	279.25	518.36		
Bare Land	0.09	0.01		
Plantation	3.15	13.51		
Total	866.34	866.34		

There was no significant difference in the variables between 2000 and 2013, but there were significant changes in variables like vegetation, cultivated, and plantation, according to Table 9 above, which tests the significance of changes in land use between 2000 and 2013.

Table 10: Magnitude of Change and Percentage Change between 2013 and 2024

S/N	*Class*	*2013 Area (km^2)*	*2024 Area (km^2)*	*Magnitude of Change (km^2)*	*Percentage Difference (%)*	*Percentage (%) Change*
1.	Water	0.85	1.23	0.38	0.04	44.71
2.	Built Up	2.13	4.09	1.96	0.23	92.02
3.	Vegetation	331.48	293.69	-37.79	-4.36	-11.40
4.	Cultivated	518.36	508.58	-9.78	-1.13	-1.89
5.	Bare Land	0.01	0.09	0.08	0.01	00.00
6.	Plantation	13.51	58.65	45.14	5.21	334.12
	Total	866.34	866.34			

Table 10 shows a 44.7% change in water, 92% change in built-up, -11.4% in vegetation, -1.9% in cultivated, 0% in bareland, and 334% in plantation between 2013 and 2024 with the negative values showing conversions into a different class of land use and its inherent environmental implications.

Table 11: Test for the significance of the changes in Land use

Class	*2013*	*2024*	*Wilcoxon Signed Ranks Test (Z-value)*	*p-value*
Water	0.85	1.23	-0.314	0.753
Built Up	2.13	4.09		
Vegetation	331.48	293.69		
Cultivated	518.36	508.58		
Bare Land	0.01	0.09		
Plantation	13.51	58.65		
Total	866.34	866.34		

Table 11 above shows the test for the significance of the changes in land use between 2013 and 2024. Since the p-value (0.753) is much greater than 0.05, the changes in LULC classes between 2013 and 2024 are not statistically significant at the 5% level. This implies that while there are observable increases in built-up areas, plantations, and water bodies, and decreases in vegetation and cultivated land, these changes do not show statistically significant differences over the 11-year period according to this test. Between 2013 and 2024, the study area experienced noticeable but statistically insignificant changes in land use patterns, with plantations showing the most marked expansion.

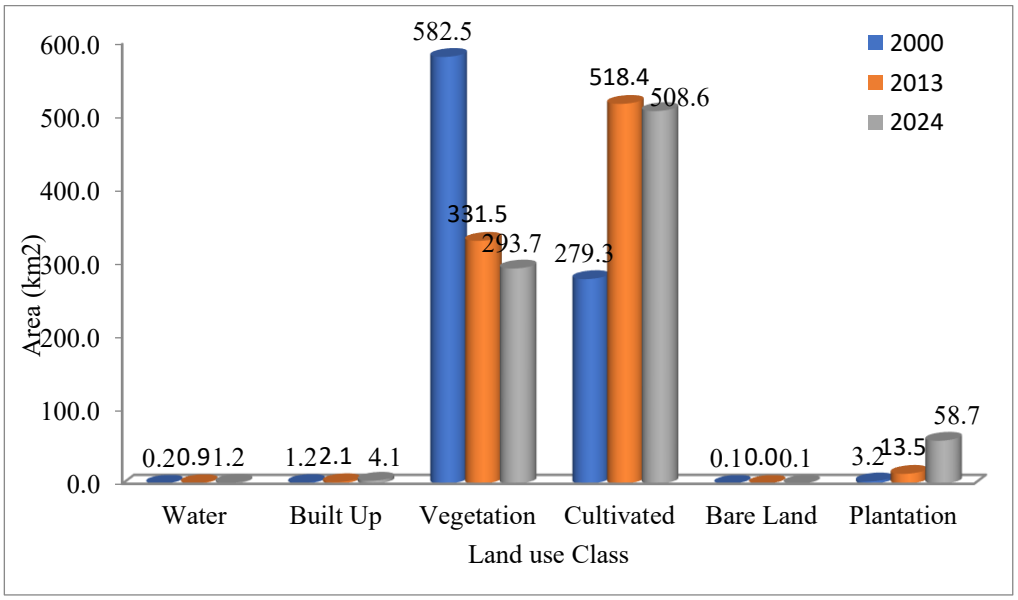

Figure 8: Land use for 2000, 2013 and 2024

Figure 8 above shows that vegetation occupied an area of 582.5km^2 in 2000 which consistently decreased to 381.5 km^2 in 2013 and 293.7 km^2 in 2024, respectively.

Cultivated area increased from 279.3 km^2 in 2000 to 518.4 km^2 in 2013 and 508.58 km^2 in 2024 while plantation increased from 3.2 km^2 in 2000 to 13.5 km^2 in 2013 and then to 58.7 km^2 in 2024. Thus, land use land cover changes show that in 2000, water covered 0.21 km^2 (0.02%), built-up area covered 1.17 km^2 (0.13%), vegetation covered 582.5 km^2 (67%), cultivated area covered 279 km^2 (32%), bare land covered 0.09 km^2 (0.01%), and plantation covered 3.15 km^2 (0.36%). From 582.5 km^2 to 331.5 km^2, or 38.3%, less vegetation was present than in 2000, when it was 67%. Plantations grew from 0.36% to 1.6%, cultivated land grew from 32% in 2000 to 59.8%, and built-up area climbed marginally to 2.13 km^2 in 2013. The area covered by water has increased from 0.21 km2 in 2000 to 1.23 km^2, the built-up area increased from 1.17 km^2 in 2000 to 4 km^2, vegetation also increased from 582 km^2 in 2000 to 293.7 km^2, the cultivated area has increased from 279 km^2 to 508.58 km^2, and the plantation has grown from 3.15 km^2 in 2000 to 58.65 km^2. The cultivated area showed steady growth, while vegetation declined sharply, indicating that deforested land was largely converted to agricultural use. This conversion partly explains the slow increase in plantation areas. The reduction in vegetation cover also contributed to a slight expansion of water bodies, which increased from 0.21 km² in 2000 to 1.23 km² in 2024.

On average, there is a clear difference in land use between 2000 and 2024, as indicated by the test of changes in land use over the period. At the 5% level of significance, the test results show a statistically significant shift in land use patterns, as reflected in the reported p-value, which is below the 0.05 threshold. This implies that at least one of the land use classes experienced meaningful change over the 24-year period. The magnitude of this change is largely driven by the substantial reduction in vegetation, much of which was converted into cultivated land and plantations, as shown in Tables 3, 4, and 5. Bare land remained almost constant throughout the study period — ranging only between 0.01 km² and 0.09 km² — indicating that nearly all cleared areas were immediately utilised for agriculture, plantations, or built-up development. This pattern demonstrates intensive land use, with very little land left idle or unused.

Impacts of Land Use Land Cover Change on Flood Susceptibility

The Land Use Land Cover (LULC) analysis significantly influences flood susceptibility within the study area. Having a total area of 866.34 km^2, dominant land cover, cultivated land, occupying 508.58km^2 (58.70%), can exacerbate flooding in some regions due to soil exposure from agricultural practices. This reduces infiltration and increases surface runoff, especially in areas with poor soil management or monocropping systems. Conversely, well-maintained agricultural land with proper drainage and conservation practices can moderate flood impacts.

Vegetation, covering 293.69 km^2 (33.90%), contributes to mitigating flooding. The presence of dense vegetation increases water infiltration, stabilizes soil, and reduces surface runoff, acting as a natural buffer against floodwaters. Plantations, which cover 58.65 km^2 (6.77%), offer intermediate benefits depending on their management, as this land cover tends to enhance infiltration and reduce runoff, their contribution depends on vegetation density and soil coverage.

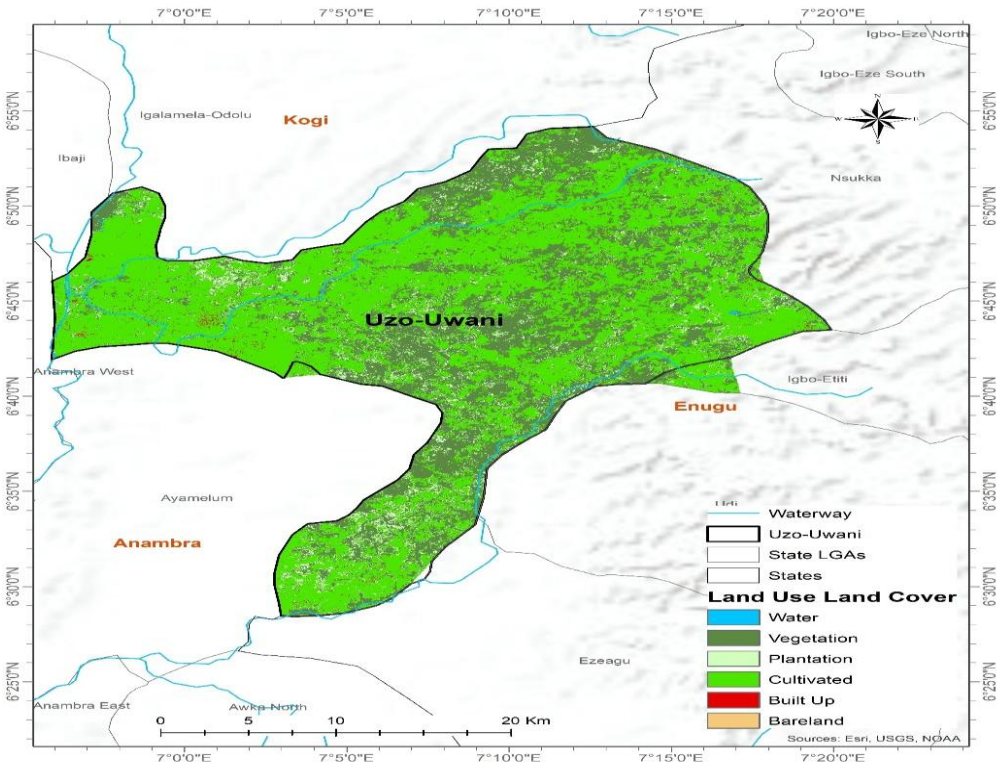

Figure 9: Land Use Land Cover (LULC) Map of Study Area

Table 12: Land Use Land Cover (LULC) Classes Distribution

S/N	*LULC Class*	*Area (ha)*	*Area (km^2)*	*Area (%)*
1.	Water	123.12	1.23	0.14%
2.	Built Up	409.41	4.094	0.47%
3.	Vegetation	29369.34	293.69	33.90%
4.	Cultivated	50858.19	508.58	58.70%
5.	Bareland	8.91	0.089	0.01%
6.	Plantation	5865.21	58.65	6.77%
	Total	86634.18	866.34	100%

The Built-up class, though small at 4.094 km^2 (0.47%), significantly influences localized flooding. Impervious surfaces in urban areas prevent water infiltration and increase runoff, contributing to flash flooding during heavy rainfall events. Water bodies, covering 1.23 km^2 (0.14%), serve as natural flood reservoirs, mitigating flood impacts by storing excess water, though their limited extent may restrict their effectiveness. Bare land, occupying only 0.089 km^2 (0.01%), has minimal influence overall, but such areas can contribute to localized flooding through increased runoff and erosion.

The land cover distribution displays that while vegetation and water bodies help mitigate flooding, the dominance of cultivated land and the presence of built-up areas necessitates careful management to minimize flood risks in the region.

Impacts of Normalized Difference Vegetation Index (NDVI)

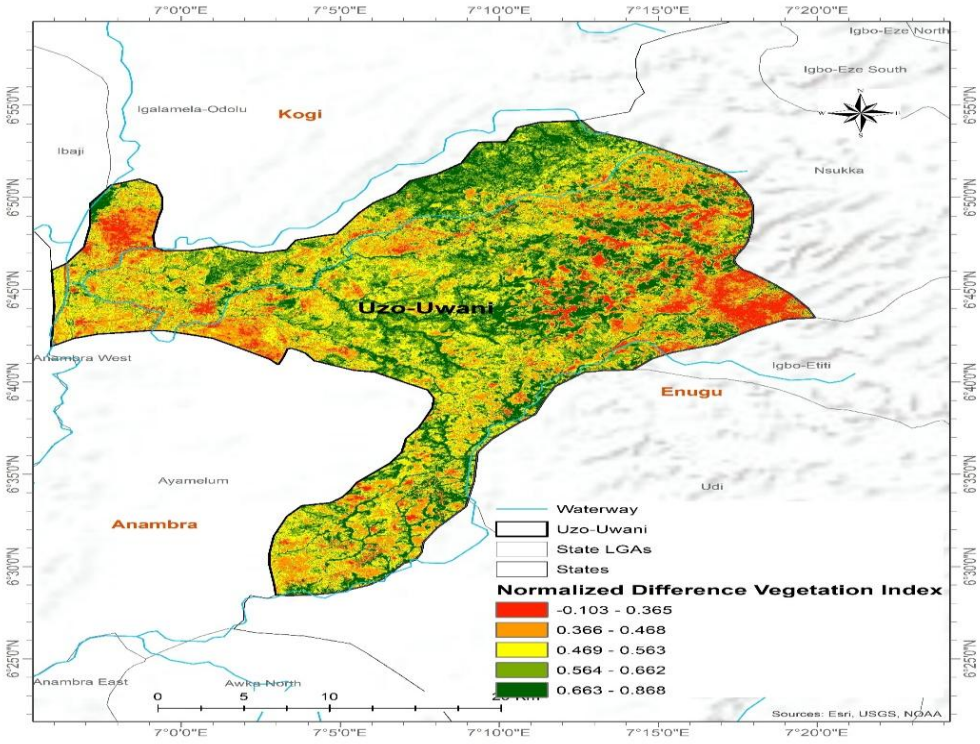

Figure 2: Normalized Difference Vegetation Index (NDVI) Map of Study Area

The Normalized Difference Vegetation Index (NDVI) values for this study report the identified land cover affecting the health and status of vegetation found in this region, with values ranging from -0.103 to 0.868. NDVI values typically range from -1 to +1, where negative values often correspond to non-vegetated surfaces such as water bodies, outcrops, etc. The low positive values represent sparse or stressed vegetation, while the higher positive values reflect denser and healthier vegetation. The NDVI for this study produces an output within the range of -0.103 to -0.365 observed land covers with minimal capacity to grow vegetation, regions having values between 0.366 to 0.488 indicate sparsely vegetated areas or degraded vegetation. These zones provide limited mitigation against flooding due to reduced water retention and infiltration capabilities. The 0.489 to 0.563 area indicates moderate vegetation cover, having agricultural land and areas with intermittent vegetation which support flood resilience, although the density of vegetation is low and need to be protected from further intensification of deforestation activities.

The vegetation type within this region 0.564 to 0.868 is good, healthy, and dense vegetation cover, such as natural grasslands, wetlands, or forests. These vegetation covers contribute significantly to reducing flood susceptibility by stabilizing soil and

enhancing water absorption, while also acting as natural flood barriers to stabilize the hydrological balance. As shown in figure 10, areas around communities like Nebo, Nibo, Abi Orobo, Nrobo, Amokwo, Opanda, Ukpabi Nimbo, Nkwelegu, Overo, Amono, Igulala, Adana, Adaba, Ukpata, Okpatu, Uzo Awan, among others indicate healthy and luxurious vegetation growth that will support good agricultural activities when compared to areas like Igbo-Etiti, Owele, Akpagu, Ogbo Uvuru, Ojjor, and Igga where identified drivers of deforestation appear stronger and intensified with the attendant environmental and agricultural consequences.

Conclusions

This research examines environmental and agricultural impacts of deforestation in Uzo-Uwani Local Government Area of Enugu State, Southeastern Nigeria and aims to assess the magnitude of change that has occurred among key environmental components like water body, vegetation, cultivated area, plantation area, bareland, and built-up area in Uzo-Uwani for a twenty years period (2000-2024) using geospatial techniques. The results show that water body increased by 1.02 km^2 representing a 485.71% change; built-up area increased by 2.92 km^2 representing 249.57% change; vegetation decreased by (-288.77 km^2) representing (-49.58%) change; cultivated area increased by 229.33 km^2 representing 82.12% change; plantation increased by 55.5 km^2 representing 1761.90% change while bareland remains unchanged.

Thus, the outcome of this research is consistent with several other studies including The Population Reports (2000) which observes that almost half of the world's original forest cover has been lost, and each year another 1 6 million hectares are cut, bulldozed, or burned. Forests provide over US$400 billion to the world economy annually and are vital to maintaining healthy ecosystems. Yet, current demand for forest products may exceed the limit of sustainable consumption by 25 percent with its attendant environmental implications as forests absorb carbon dioxide and produce oxygen, anchor soils, regulate the water cycle, protect against erosion, and provide a habitat for millions of species.

The test of change in land use components revealed no significant difference or change in the land use between 2000 and 2024 which is evident by the p-value of the test statistic of 0.50 being greater than 0.05, hence at 5% level of significance. While acknowledging limitations associated with reliance on secondary satellite data, classification accuracy, and statistical tests in carrying out this study, it is recommended that future research can adopt finer-scale socio-economic surveys, integration of climate data, or long-term monitoring of environmental variables.

It is worthy of note that existing researches mostly focus on regional dimension of environmental consequences of deforestation, leaving a knowledge gap regarding the local dimension for communities like Uzo-uwani, a critical agricultural region in Enugu State, dealing with escalating flood disasters causing significant socioeconomic damages. This lack of understanding hinders effective disaster response and mitigation efforts for communities within Uzo-Uwani L.G.A. This research thus provides critical information for targeted interventions which will ultimately support the communities and empower them to take proactive measures, support the development of government

policies on environmental protection, urban planning and climate adaptation strategies in the region. We therefore recommend promoting agroforestry in cultivated expansion zones, or community-based monitoring in plantation areas as well as taking other proactive and remedial measures to conserve and preserve the environment.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*	*Author 6*	*Author 7*	*Author 8*	*Author 9*	*Author 10*
Conceived and designed the research or analysis	Yes	Yes	No	No	No	No	No	No	No	No
Collected the data	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	No	Yes	No	No	No	No	No	No	No	No
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supervision	Yes	Yes	No	No	No	No	No	No	Yes	No
Project Administration	Yes	Yes	No	No	No	No	No	No	Yes	No
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Overall Contribution Proportion (%)	15	20	8	8	8	8	8	8	9	8

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